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Introduction to Metalliferrous Mine Working

Entrance for Underground mines:

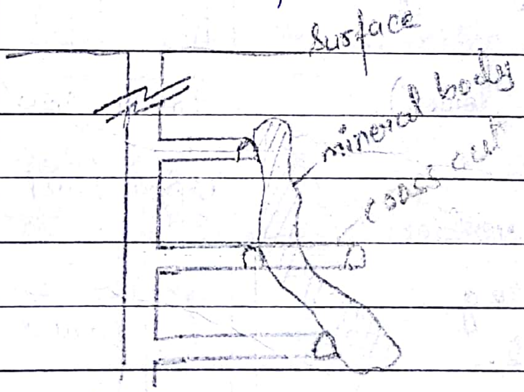
There are three type of opening to enter in U/G mines:

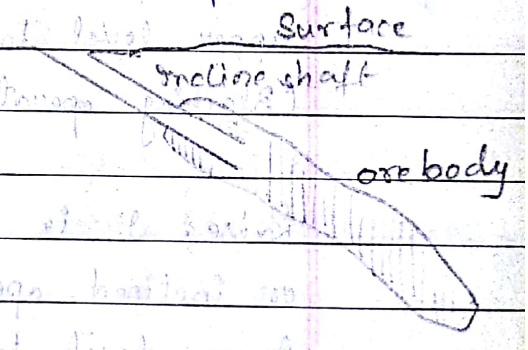
1. Shaft
2. Adit
3. Decline

1. Shaft :- It is an entry or exit, from surface to U/G or from U/G to surface. It is utilised for men winding, material & machinery winding and mineral and waste winding for use of year rounds.

It may be two types:

i. Vertical Shaft   ii. Inclined Shaft.





i. Vertical Shaft: It is a vertical opening like 'well' to access the mineral.

ii. Inclined Shaft :- It is an inclined opening to access the mineral.

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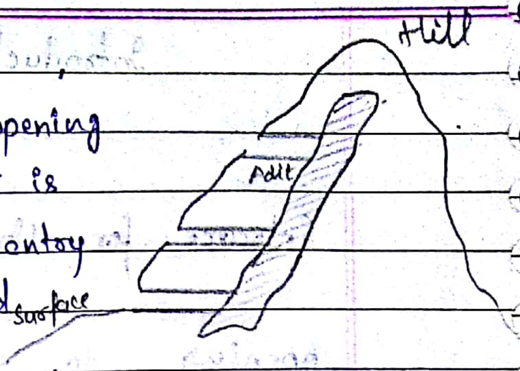
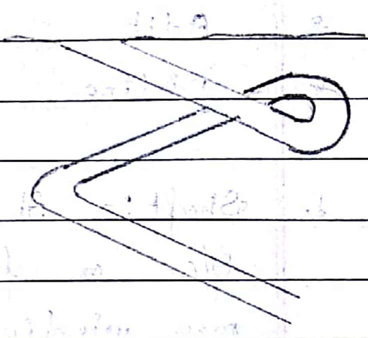
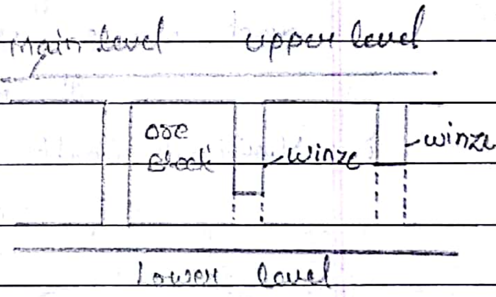
2. **Adit :-** It is a horizontal entry or opening to the ore body of the hill that is known as adit, when one end of entry is open to sky and the other end meet to the mineral.



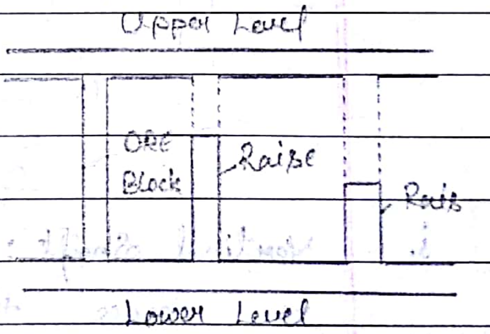
3. **Decline :** It is spiral inclined opening to access the mineral. It is also called a trackless mine in which L.H.D. L.P.D.T. are playing to transport the mineral.



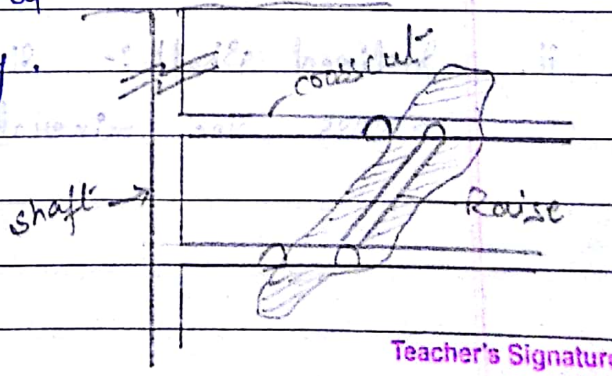
Winze : It is an downward vertical or inclined opening for joining upper level to lower level.
(Blasting operation upper to lower)



Raise : It is an upward vertical or inclined opening for joining lower level to upper level.
(Blasting operation lower to upper)



Cross cut :- It is a horizontal opening across the ore body.



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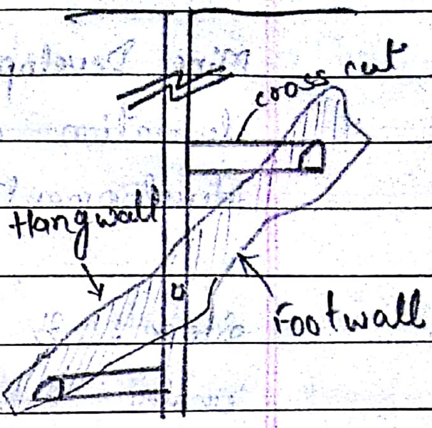
Hangwall: The strata resting on the ore body is known as hangwall.

Footwall: The strata is resting under the ore body known as foot wall.



Level: When the horizontal drivage (development) is driven in the ore body, it is known as level. It always in strike direction.

Companion level: When the horizontal drivage is driven at some distance from the ore body. It may be driven parallel to ore body.

Main level: Those levels which are used as haulage level for transporting ore.

Sub-level: It is a horizontal drivage between two adjacent level that connects the two adjacent raise or winze.

Footwall drive: when the drivage is driven into the footwall of ore body.

Hang wall drive: When the drivage is driven into the hangwall side of ore body.

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Mine Development: The drivage made in U/G for formation of ore blocks or pillar is known as development.

Stope: It is a solid block or pillar which is under extraction, known as stope.

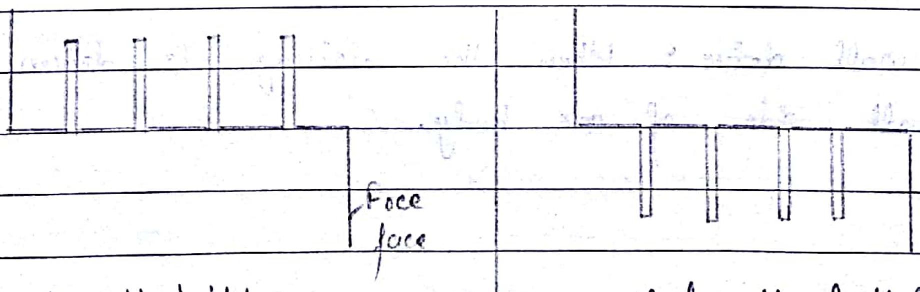
Stoping: It is the operation of extraction of solid ore blocks or ore pillar.

Crown pillar: When the small thickness of solid ore body is left for the protection of lower level. It is known as crown level.

RIB Pillar: A pillar which is left in between two adjacent stope, is known as RIB pillar.

Ore Pass: An opening which is utilize to transfer ore under gravity from upper level to lower haulage level.

Over hand hole: When the blasting hole are drilled above over head in upward direction.



Over Hand Hole   Under Hand Hole

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Under hand hole :- When the blasting holes are drilled below the foot in downward direction.

Ore Chute / Chute :-
It is an opening or window provided/installed in the ore pass / waste pass at lower end of mouth of raise or winze from where loading of material/ broken ore/ broken waste in mine cars is done. Such type of arrangment is known as chute. It is made of iron/ steel plates and girders or timber planks also.

Drive/ Drift :- A horizontal tunnel or roadway parallel to strike of the lode/vein/ mineral body but it can be located into the country rock either on footwall side of lode or on the hangwall side of lode.

Cross drift (Cross drive) : It is a horizontal U/G roadway driven within the ore body b/w the hangwall and footwall. It is usually at right angle to the drive drift.

Reef drive :- It is in the vein itself or partially in the reef and partly in the wall rock, usually in foot wall side.

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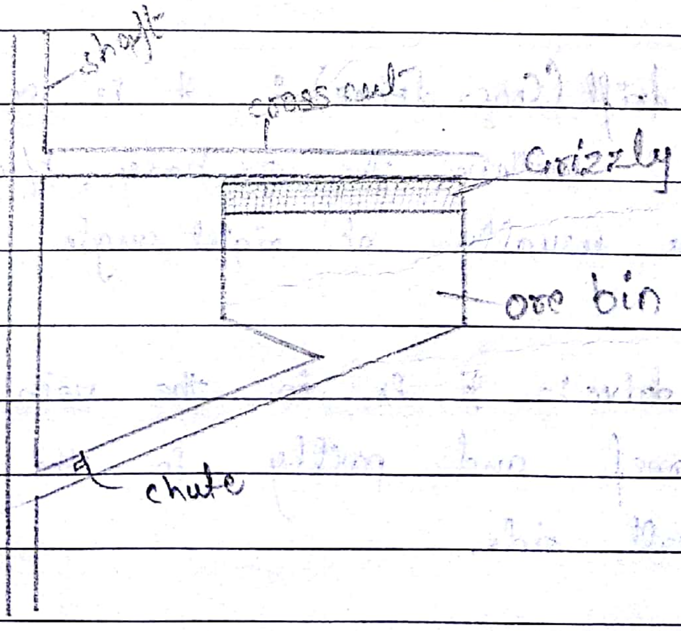
Man hole :- Manhole is a narrow recess (pocket) made in the side of haulage roadway for workman to take shelter when rope/ loco/ L.H.D/ Dumper is in motion. Such manhole must be not less than 0.75 m & not more than 1m in width and not less than 1.8 m height. Such manhole should be well white wash.

Grizzly :- It is a screen made up of heavy girder. It is fitted or installed at the top of bin (Ore / waste bin).

Bin :- In U/G excavation, it is used to store broken rock (ore / waste). Such broken rock goes downward under gravity and the lower end of the bin is installed with chute. Such chute is utilise to load mine cars for transport of the broken rock.



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Limitation of U/G mining :-

i Stripping ratio = $\frac{\text{Volume of Over burden in } m^3}{\text{Weight of recoverable mineral reserves in tonne}}$

ii Economics of ore
iii Mining Machinery
iv All type of geological information; such as dip of ore body
v Type of deposites ; flat/Vertical/ Inclined.
vi Depth of ore body.
vii Skilled men power is required.
viii Skilled Technical work persons are required; like Engineers and technisions.
ix Safety standards is very high.
x Minimum, there are two outlet enteries required.
xi Distance b/w two enteries should not be less than 13.5 m.
xii Each outlet shall be connected with walkable passage ; not less than $1.8 \times 1.5\ m^2$ through out the warking U/G

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The Alimak Raise Climber :-

The alimak raise climber consists of :

1. A reel with air hose to provide compressed air to the twin air motors causing travel of the cage. The reel automatically winds up the hose when the raise climber descends and feeds it during ascent.

2. Compressed air hose-pipe 1" ϕ (dia)

3. Guide rail with rack and pinion. The guide rail comes in length 1-2 m. Some pieces are suitably curved for a smooth profile. The guide rail pieces are bolted onto the rock. The guide rails have recesses to cary 2 compressed air tubes, 1 water tube. ~~and~~

4. The rock bolts are of expansion shell type.

5. A cage that travels along the guide rail and carries the driller and other crew to the face of the raise.

6. The working platform on top of the cage.

7. Compressed air drive unit with air motors for travel of the ca

8. Protection canopy.

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Operation :-

The alimak raise climber can be used only where the raise is driven at an angle of 40° or more with the horizontal. ~~since~~

The cage alongwith the platform and canopy can be made to travel along the guide rail by the drilling crew from the cage with the help of air motors. At the face of the raise, the drillers drill the shot holes with Jack hammers / Stoper drill machine standing on the platform and well protected by the canopy. Two Jack-hammer can be operated at a time. Drilling over, the shot-firer charges the holes with explosive from the platform. Before blasting the workers come down in the cage so that the cage and platform can be lowered and parked at a safe place, away from damage by blasting rock. After blasting, water and air are supplied through the guide rail to clean away the fumes by a mist of water and air and to ventilate the face. After maintain ventilation loose rock should be proper checked by loose bar and after small size of hammer. The workers then climb upto the face and the guide rail is then extended by first fitting the rock bolt to the side and then anchoring the rail extension piece to it.

Drilling :- We use Burn-Cut drill pattern to develope the raise face. Stoper drill machine / Jack hammer drill is used which is operated by compressed air of 75 - 90 lb/ inch^2. We are using tungston carbid drill rod starter $2\frac{1}{2}$' then 4', 5' and 6'

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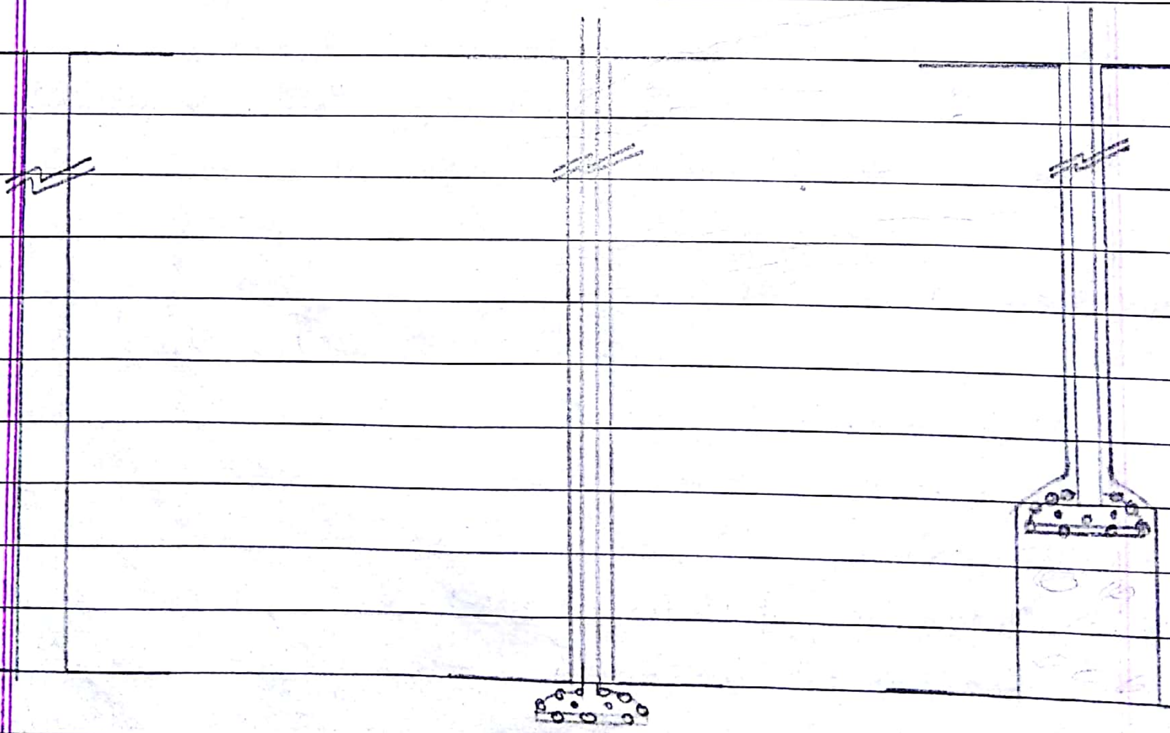
Safety System on Alimak Raise Climber :

1. Protection canopy to protect workers head and body by the rock bolders falling down during drilling & loose dressing.

2. An air operated brake which is automatically activated when air for the motors is shut off, and if the speed exceeds 0.9 m/s the climber will be locked to the guide rail.

3. An over speed controlling safety devices there is a speed regulating break.

* **Raise Borer :-**



Drill a pilot hole — attach a reaming bit — Reaming Process

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This method is suitable for homogeneous strata. In this system of raising, a machine raise borer/ Down the hole (D.T.H) drill is used. First, drill a pilot hole of 165 mm dia from upper level to lower level then inlarge the dia a hole to 200-300 mm through the length. The process of inlarging the hole dia is known as reaming. If the pilot hole is reamed from upper level to lower level, is know as down reaming method. It demands large dia of pilot hole to permit rock cuttings to pass through the space between drill rod and the ~~of~~ side of the hole. If the pilot hole is reamed from ~~upper~~ lower level to upper level is called up-reaming and it does not required large dia of pilot hole. The up-reaming method is commonly adopted the most.

To ream the pilot hole of 200-300 mm dia from lower level to upper level, a required size of drill tool is attached to the drill rod (string) at the lower level and grinding of rock starts from lower level in the upward direction.

Progress achived by this method average between 100-150 m of raise per month.

The speed of drill tool is 15-20 rpm at starting but it will be slower in the last ~~of~~ about 12-15 rpm.

Advantages :-

i. It is the safest method of raising because men do not travel in the raise.

ii. Operation cost is less.

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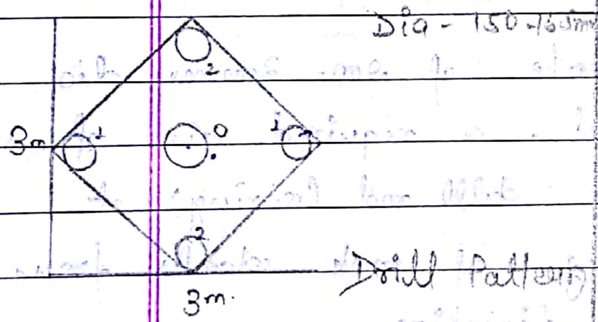
iii. No explosive is used.
iv. There is no loose formation.
v. Getting smooth wall by which less resistance of flow of air and ventilation will be proper.

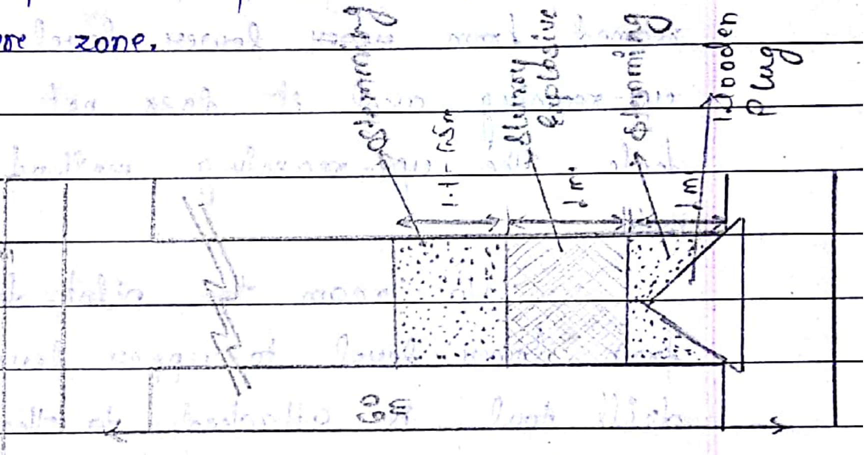
Disadvantage :-

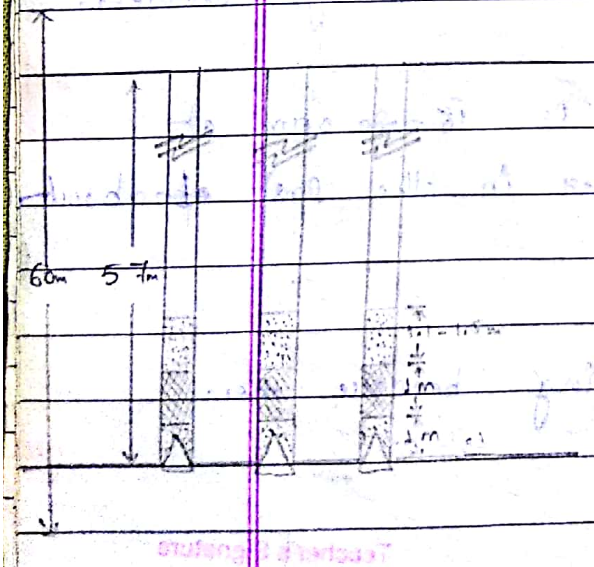
i. The capital cost is more.
ii. This method can not be adopted if any geological disturbance in rock mass like multi slips, joints, fault or fold is found.
iii. Recovery is not possible of drill tool which when jammed in fracture zone.

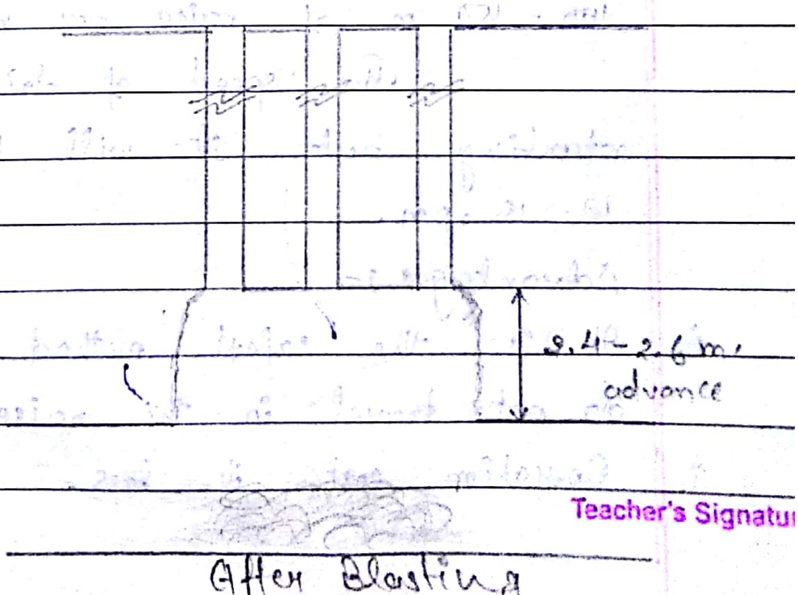
* **Drop Raising :-**



Drill Pattern







After Blasting

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This is a method of making raise, connecting between two adjacent level, nearly 60 m apart, by drilling large dia holes (150 – 165 mm) through, from upper level to lower level and blast them in stage. The raise is usually vertical by may also be steeply inclined. For a 3x3 m^2 raise, the blast holes are 165 mm dia, 5 in number (1 in centre & 4 at corner) drilled from the upper level to lower level nearly 57 m. A wooden plug in two pieces tied together by nylon/ plastic rope is lowered into the blast hole to plug the bottom mouth of the blast hole. The charging of blast holes is done from the upper level. The blasting practice of holes is done with spherical charge ratio of L:D :: 6:1 or L:D :: 4:1 (where L = Length of charge hole and D = dia of holes.

First nearly 1 m length is steammed by stemming material / cutting material and after that charging the hole by slurry explosive cartridge in which primer is prepared by cordex and delay element is fixed with cordex at the surface. Above the charging, a length of 2 – 1.8 m is packed with cutting material / sand and rest of the hole is left unsteamed.

All the five holes are charged and they are blasted in a sequence with the help of delay detonaters. After a blasting, the raise is advanced by 2.4 – 2.6 m.

~~Advantages~~ :–

i) It is ~~the~~ a ~~fastest~~ method. A raise nearly 57 m long is completed with in a period of about 20 days.

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Open raising method or single compartment method :-

This method is conventionally adopted for raise of moderate length & inclination of 40° to 60° if strata are strong.

One or two round are drilled standing on the muck but later on a plateform is made of timber planks supported on iron bars fitted into the foot wall. The drilling of holes is done by jackhammer. holes are of 32 mm dia and 1.5 m deep. Before each round is blasted, the plateform is ~~dismelt~~ dismentled. After blasting, compressed air is forced to the working ~~forces~~ faces to remove the fumes of blasting and for ventilation. The broken rocks rolls down by gravity.

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Double compartment method :-

This technique is an improvement over the single compartment method. This method involves dividing the raise into two compartments, one of the compartment is known as mainway compartment. It is used to install service line such as water line, ventilation duct & ladder. The other compartment is used to accomodate the blasted muck. The parking is build by fixing the wooden slippers in centre of the raise. After every blast, the muck is drawn from the bottom so that it level is maintain at same height as that of the mainway compartment. Before blasting any round, the mainway compartment is covered using an inclined wooden plank to divert the blasted fragment toward the muck compartment and thereby avoiding any damage of its fitting.

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Unit - 03 Method of Working

Selection of stoping method:

Selection of proper stoping system and deploying matching method, equipments and techniques. The following factors which governing choice of mining method are as:

i Shape & size of the deposite
ii Thickness of deposite
iii Dip of deposite
iv Depth of the deposites
v Presence of geological fault and geological disturbence and influence of direction of cleat and parting.
vi Degree of mechanisation and output require.
vii Ore grade and its distribution along the strick line
viii Value of the product (economically)
ix Presence of water and gases
x Nature of the ore and country rock, and its chemical action like oxidation

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Classification of Stoping Method

U/G Metal Mining Method

Ore Strength & Rock Strength	Strong to Moderate				Moderate to weak			Moderate to weak cavable		
Stoping class	Unsupported				Supported			Caving		
Deposite Geometry	Tabular Flat Thin Large size	Tabular Flat Thick Large size	Tabular Steep Thin any size	Tabular steep Thin Any size	Variable shape Steep Thin Any size	Tabular steep Thin Any size	Any shape any dip Thick Small size	Tabular Flat Thin Large size	Tabular & massive Steep Thick Large size	Massive Steep Thick Large size
Name of working Method	Room & Pillar	Stope & pillar	Shrinkage Stope	Sub level Stoping	Cut & fill	Stull Stoping (Breast stoping	Square set Stoping	Long wall mining	Sub level Stoping V.C.R.	Block Caving

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V.C.R. Stoping Method :–

Conditions :–

i. Dip : Moderate to steep
ii. Strength of ore & walls : Strong
iii. Thickness of ore body : Moderate thickness
iv.

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The method employs large dia long holes of 152, 165 or 200 mm dia. A charge is considered to be spherical charge if its length : dia does not exceed 6:1. Thus for a hole of 165 mm dia, a slurry package of 165 mm dia and 990 mm length would form a spherical charge.

The V.C.R. method requires large dia holes usually of 165 mm dia, to be drilled in a parallel pattern from a ~~top~~ upper level to lower level. When the drill pattern has been completed over the whole stoping block, the bottom of each hole is blocked off and charge with spherical slurry bags. The holes are then blasted, the broken ore is then drawn off from draw point by L.H.D.

Repeating this loading and blasting procedure. The blasting is done from bottom of hole into block in vertical upward direction.

Advantage :-

i. Reduce dilution of ore.

ii. Improvement in fragmentation.

iii. Lower development cost since it eliminates rais boring and slot cutting.

iv. Increased safety of operation because drilling & blasting carried out from above.

Higher tonnage per day.

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Cut and fill stoping :-

Conditions :-

i. Dip : Moderate to fairly steep
ii. Ore strength : Moderate to strong
iii. Rock strength : Weak
iv. Ore grade : Fairly high
v. Deposite size : Narrow to moderate width
vi. Deposite shape : Tabular, can be irregular

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In this method, the ore is excavated in horizontal slices starting from the bottom of the stope and advancing upward. The broken ore is loaded and completely removed from the stop. When one slice of the ore has been excavated the corresponding volume is filled with waste material. The filling material can consist of waste rock from preparation, distributed mechanically over the stoped out area. In modern cut and fill method however, the hydraulic method is normal practice. The filling material here consists of fine grained tailing from ore dressing plant or sand mixed with water transported into the mine and distributed through pipe line. When the water is drained off a competent fill with a smooth surface is produced. To provide proper drainage of the fill while it sets percolation drains (perforated pipes) are installed along the stope.

Advantage :-

i. High recovery of ore is possible.
ii. Dilution of ore is reduced.
iii. Waste reused as fill
iv. Ventilation is comfortable.
v. Low development cost.

Handling of waste - extra cost
Filling complicates cycle of operation causing discontinuous pro

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Sub level Stoping :-

Condition :

i. Dip: Steep
ii. Ore strength: moderate to strong
iii. Rock strength: Strong.
iv. Ore grade: Moderate
v. Deposite shape: Tabular and defined boundaries

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Staping starts from a slot at one end of the stope, sometimes a slot is made at the centre of the stope. The slot is made by stripping a slot raise from wall to wall (F/w to H/w) by parallel long hole drill. Rings of long holes are then drilled from the sublevels and blasted into the slot.

Rings of 45 - 60 holes (52 & 57 mm holes are most prevalent) are usually drilled. Burden on rings is generally kept at 30 times hole dia while a large toe spacing 50 times hole dia is adopted b/w holes in a ring. Parallel hole drilling is superior to ring drilling. It ensure lower specific drilling and blasting compared to ring drilling.

Advantage :-

i. Mechanisation in drilling, loading and transport is possible
ii. Low man power required
iii. Operation cost is low

Disadvantage :

i. Selective mining is difficult.
ii. Preparation work for stoping is heavy and sometimes complicated.

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In block caving, the ore is divided in large blocks with a horizontal cross section usually larger than 1000 m^2. At the bottom the block is completely undercut i.e. a horizontal slot is blasted, which removes the support of the over-laying ore.

The undercutting, creates a series of fractures in the ore-body which gradually affects the whole block. The ore at the lower part of the block is crushed by the cracked upper portion and gives a fragmentation which allows the ore to be drawn through a net work of finger and branch raises and draw points. The drilling and blasting is required only in the lower portion of ore body. The upper portion caves down.

Advantage :—

i. Operation cost is low.
ii. After the caving starts a high rate of production is possible.
The

Disadvantage :

i, Caving of block is difficult to control.
ii) Ore dilution is more.
iii, Secondary blasting is required on a large scale as big chunks of ore come down during caving.
iv. High mechanisation is possible only to a limited extent.
v. Selective mining is not possible.

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Square Set Stoping :-

Condition :

i. Ore Strength : Weak to very weak.
ii. Rock Strength : weak to very weak.
iii. Shape of Deposite : Any, regular to irregular.
iv. Dip : Steep
v. Size of Deposite Any size
vi Ore grade : High
vii Depth : Upto 2.5 km.

Preparation :

i. Level interval (vertically) : 30 m.
ii. Size of Level : $1.8 \times 2.5\ m^2$

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Square set stoping is the method of mining in which the walls and back of the stope are supported by regular frame work of timber called square set.
It consists of member known as Girt & Cap are usually 1.8 - 2.4 m in length whereas post (vertical member) are 2.4 - 3.0 m height.
The important feature of these type of support is that it can be extended in any direction by adding the member to cover the complete excavation that need immediate support after its exposure so that a support net work like a nest is built within the stope.

Advantage :-

i. Irregular ore bodies of any shape may be worked by this method.
ii. It can be adopted where the ground conditions are bad.
iii. Waste rock can be sorted out and allowed to remain in the stope.

Disadvantage :

i. A large quantity of timber is required. It constitutes of a fire hazard.
ii. Production of ore is low and the O.M.S. is poor.
iii. It is a labour intensive method.

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Breast Stoping :-

Condition :-

i. Dip : Moderate to 45° (30° - 45°)
ii. Thickness of Ore body : 0.5 m - 1.5 m.
iii. Nature of H/w & F/w : strong but H/w is slightly weak than F/w
iv. Strength of Ore body : Strong

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In this method ore is broken by flat or slightly inclined holes drilled in a vertical (or nearly vertical) face of considerable lateral area which is being advanced in a nearly horizontal direction. The face is in dip-rise direction and mining proceeds along the strike. Breast stoping is a low cost simple method much preffered for low grade ore deposits where supporting ore pillars may be left.

Stoping is commenced from raise driven from haulage way. The broken ore is slushed to ore chute by scraper hoist installed in special recess (pocket). The worked out space is supported by irregular pillars, timber cribs and individual props.

Advantage:

i. Higher mechanisation is possible
ii. Selective mining is possible.
iii. Mining cost is low.
iv. Simplicity

Disadvantage:-

i. It needs for keeping a constant watch on the condition of the back.
ii. Such type of stoping is only applicable where ore thickness is 0.5-1.5m
iii. More man power are required to cycle operation of the stoping.
iv. Large no. of timbers are require to support its H/W.

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Shrinkage Stoping

Conditions:

i. Dip: Steep (60° – 90°)

ii. Nature of ore body: Strong

iii Nature of H/w & F/w: Strong to fairly strong

iv. Size & thickness of deposite: Narrow & large extend (30 m) but not below 1 m.

v. Depth of the working place: Practically upto 750 mt

vi. Ore grade: Fairly high.

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In shrinkage stoping the ore is excavated in horizontal slice, starting from the lower part of a stope and advancing upward i.e towards the rise. Advances up the rise with mining is maintained by balancing "swell" and "shrink" A characteristic feature of shrinkage stoping is that a part of the blasted ore is left in the stope where it serves both as a working platform for drilling and as support for the stope walls. Shrinkage stoping is based on the fact that when a solid rock is broken by blasting, the broken rock fragments occupy a large volume. The increase in volume may vary from 30% to 70%. To maintain a suitable working space for miners, it is necessary to shrink the muck pile a correspondig amount, nearly 40% by drawing some of the broken ore out as the stope is advanced. Recovery of the ore varies from 75-90% and it is lowest in thick deposits.

Advantage:-

i. More efficient and cheaper

Selective mining is possible.

No ore passes require.

No scraping of ore is required.

Disadvantage:-

i. High mechanisation is not possible.

ii. More man power required

iii. There is possibility of spontaneous combustion in ore with a high sulpher content.

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Overhand Stoping :-

Conditions :-

i. Dip: Moderate - steeply dip
ii. Thickness of ore body: Min (0.5 - 1.5/2 m)
iii. Nature of walls: Strong
iv. Nature of ore body: Easily separated from H/w & F/w

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This method is applicable where two levels enclosing an ore block and connected by raises at intervals (25-40m). The stoping operation proceeds from lower level towards upper level and the ore is extracted in steps like benches in an ascending order. This method is commonly employed in steeply dipping narrow veins and also in bedded deposits of 2-3 m thick. A bench is pushed 2-4 m thickness. The ore is drilled by compressed air drills and then blasted. The blasted rock fall down under gravity along footwall and is loaded into tubs or mine cars through drawpoints equipped with chutes. A crown pillar is left for support of upper level. The wall rocks may be supported by stulls or by pillar left purposely if the ore is lean. If the orebody has a mild gradient which prevents gravitation of blasted ore, scrapers are used to collect and load it into mine cars. The sill pillar left above the haulage level is 2.5 - 3.0 m thick and it protect the lower level.

Disadvantage:

i. Higher mechanisation is not possible.
ii. Production may not increase.
iii. More supporting material required.
iv. The place is not safe for working because man have to work under the exposed loose ground.

Advantage :-

i. Suitable for thin overburden.
ii. Better fragmentation.
iii. No secondary blasting is require.

Teacher's Signature

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Under hand Stoping :-

Condition :

i. Dip : Moderate to steeply
ii. Thickness of ore body : (0.5 - 2.0 m.) thin
iii. Nature of wall : Stronger
iv. Nature of ore : Strong

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This method is used where thin steeply dipping veins enclosed in strong wall rocks. The stope is worked in a downward direction from upper level to the lower level. At the upper level, a crown pillar along the strike of the orebody is left for support of the main level except for a few openings to reach the ore area to be stoped out. The blasted ore at the faces has to be shovelled down. The handling of the extracted ore is a labour consuming process unless the dip of the vein exceeds about 40°. With the progress of work as the benches descend towards the lower level, the large areas of exposed wall rocks need to be inspected and tested regularly.

Advantage:-

i. Increases drilling efficiency.
ii. Better fragmentation.
iii. Cost will be less.
iv. Less supports are required.

Disadvantage:-

i. More men power require to handle the extracted ore.
ii. Ventilation is also not simple.
iii. The transport of ore is poor.

Teacher's Signature

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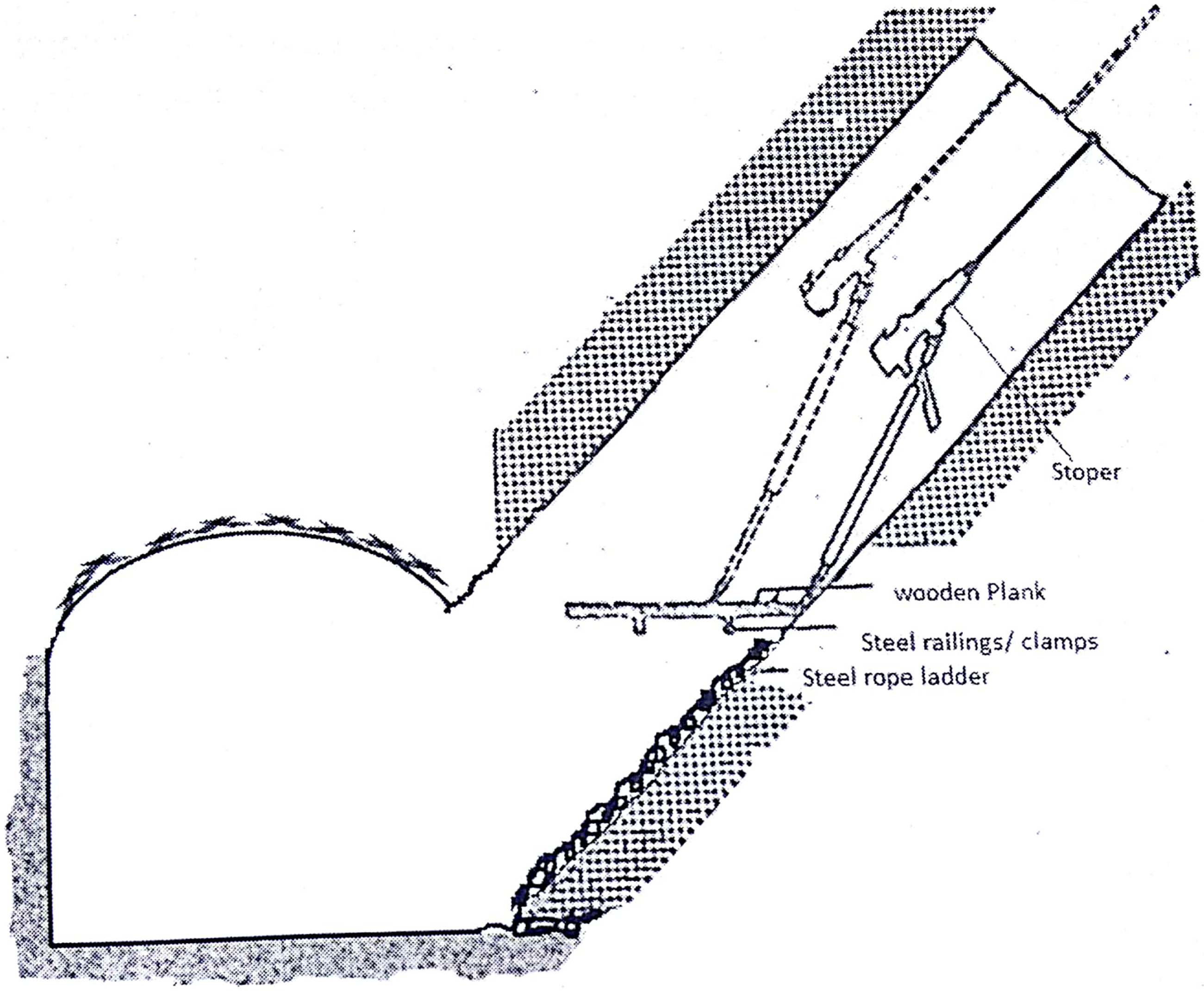

Fig. Manual Raising method

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drawbacks of the metho...
g a number of subsidiary tasks (like building ...
and repairs, etc.).

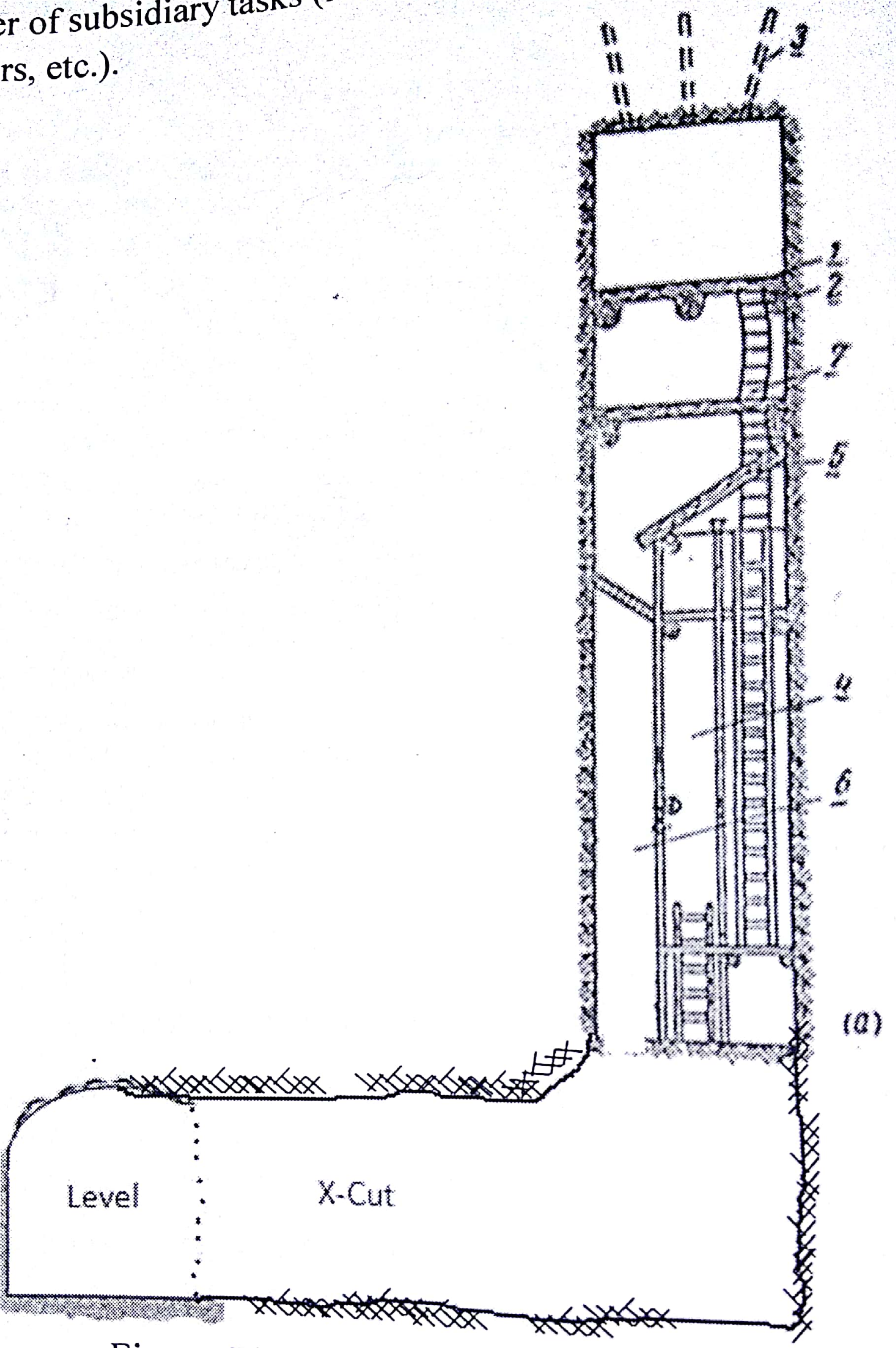

Fig. Fig. Two compartment method

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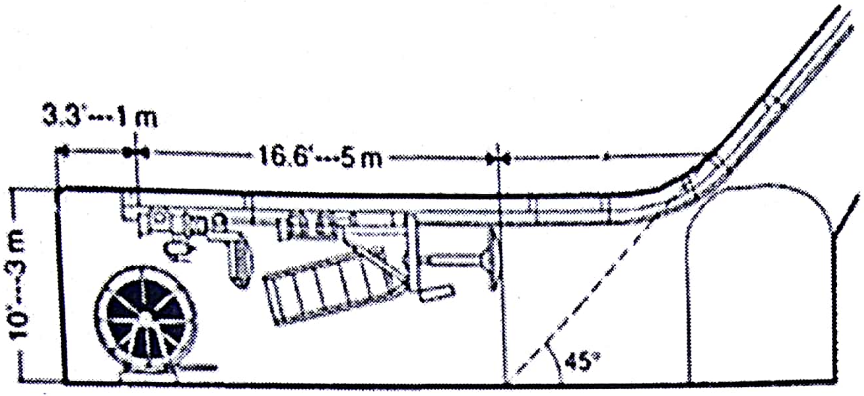
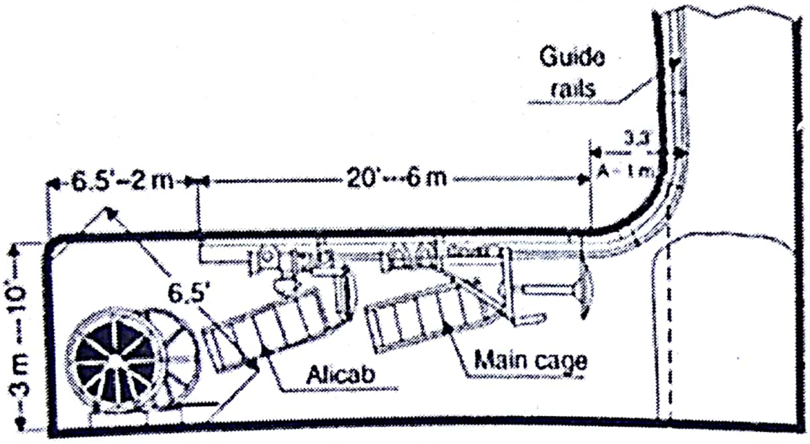
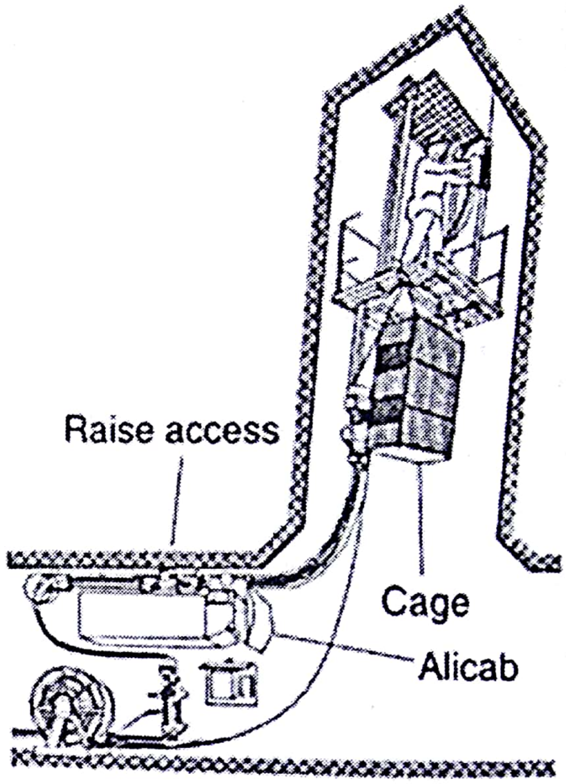


(a) Equipment for an inclined raise



(b) Equipment for vertical raise



(c) Alimak raise climber

Fig. Preparatory work for installation of Alimak raise climber

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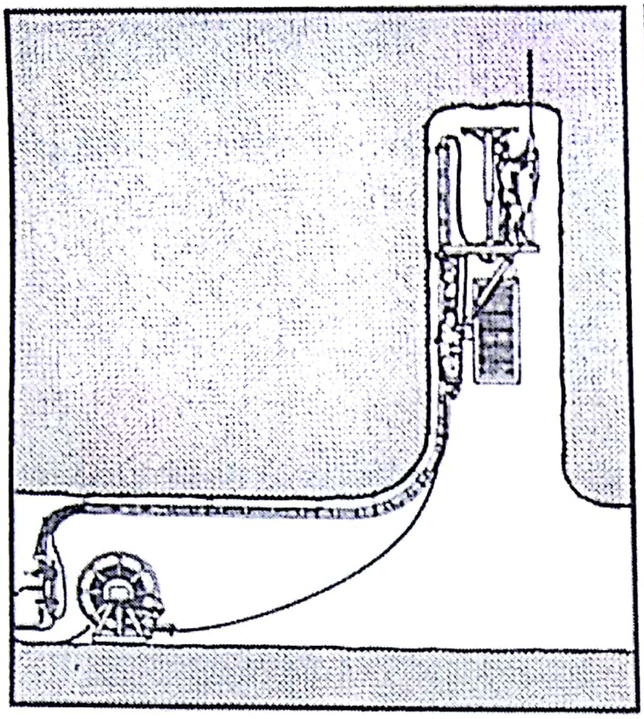
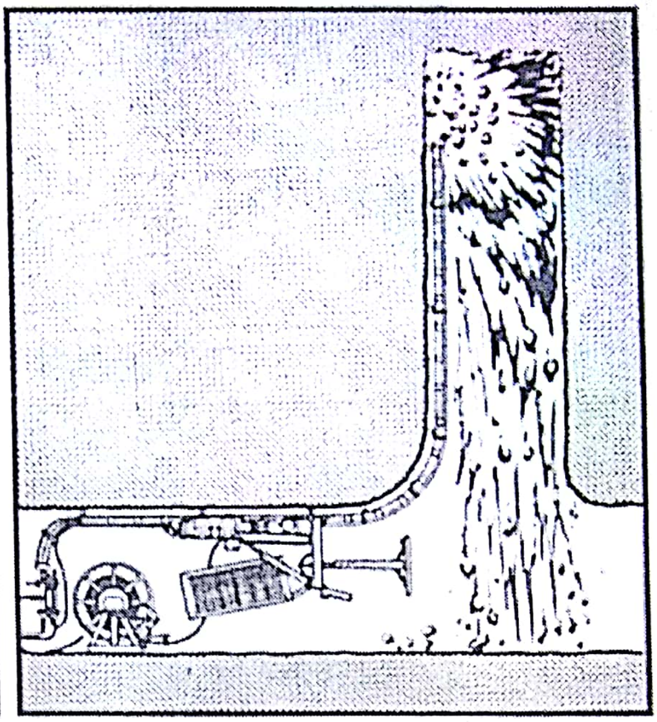


(a)



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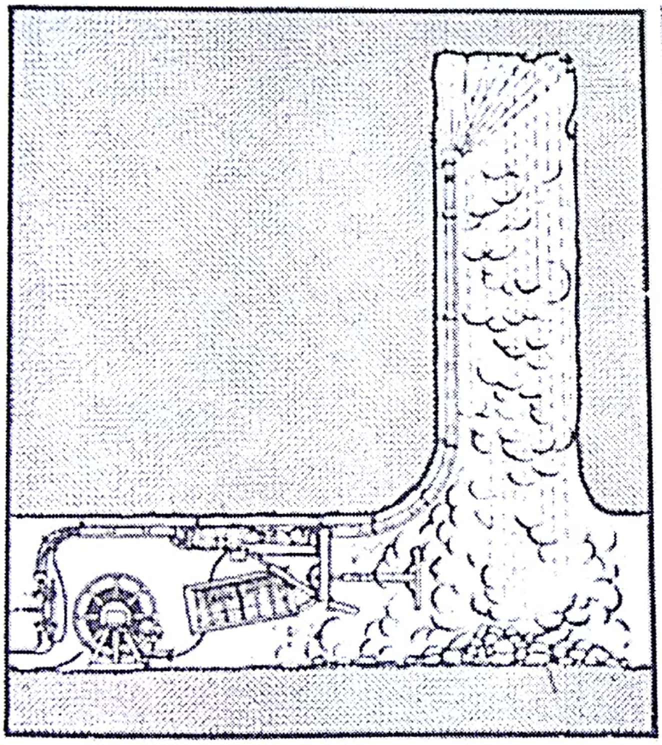

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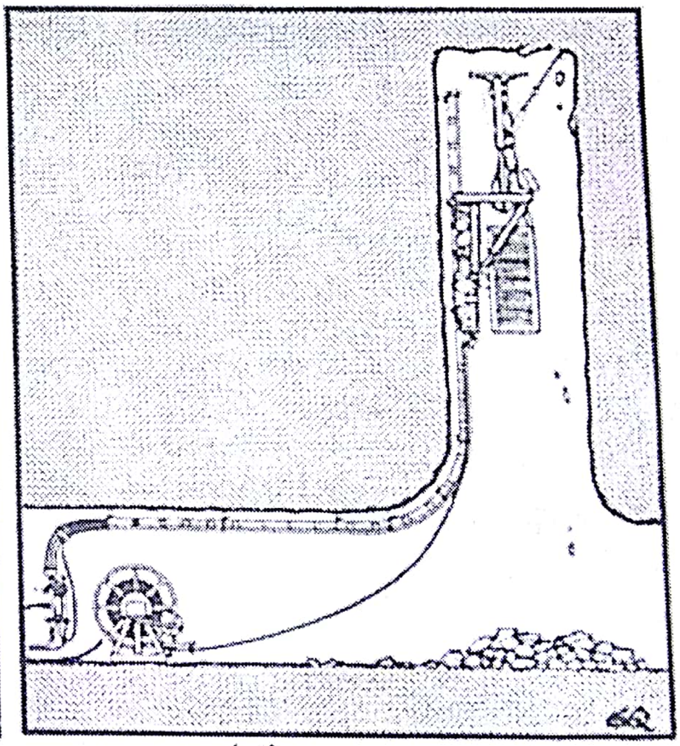

(d)

Figure Steps of operation in Alimak raising method.

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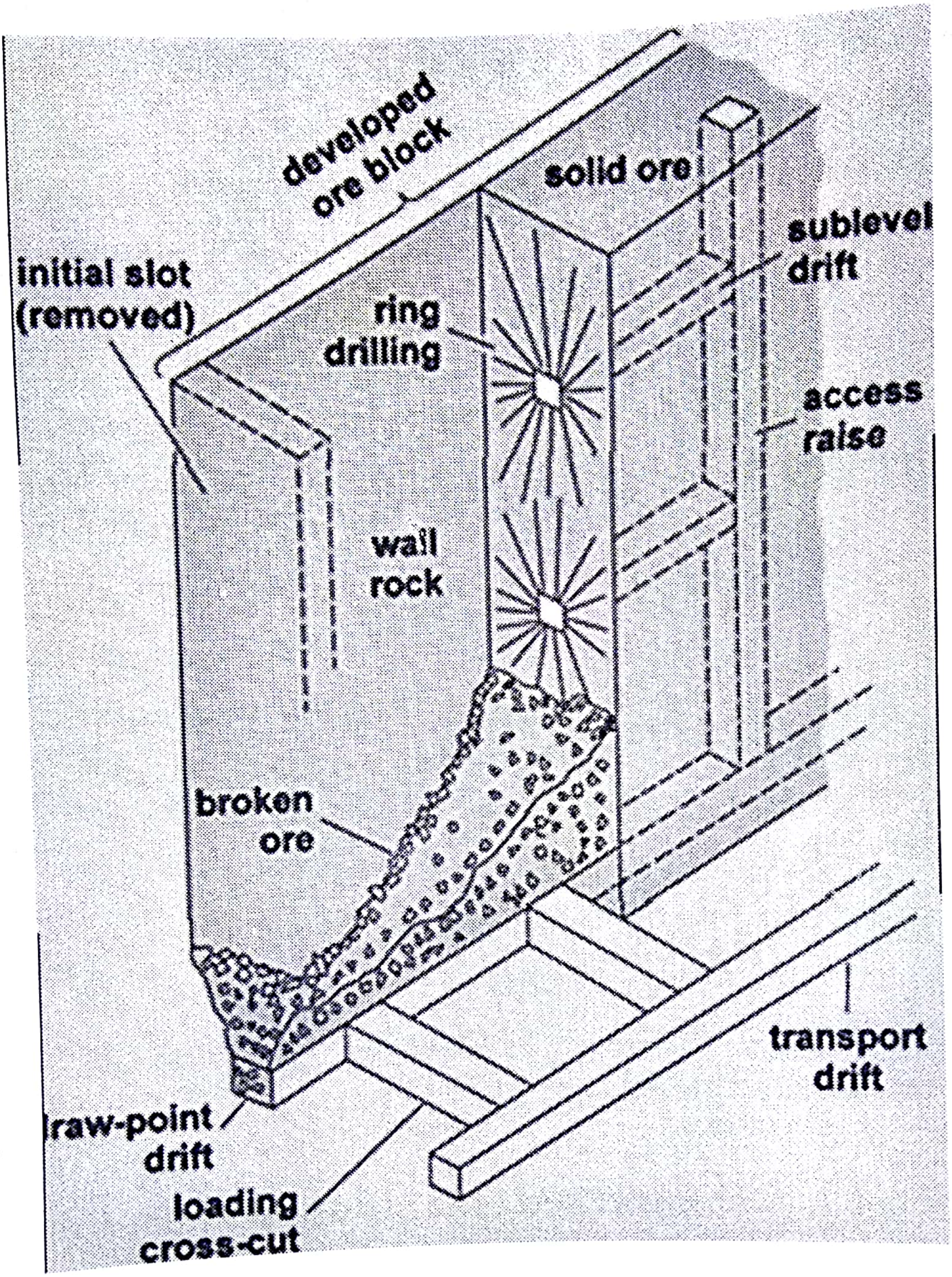

Figure Ore drawal in sub-level stoping

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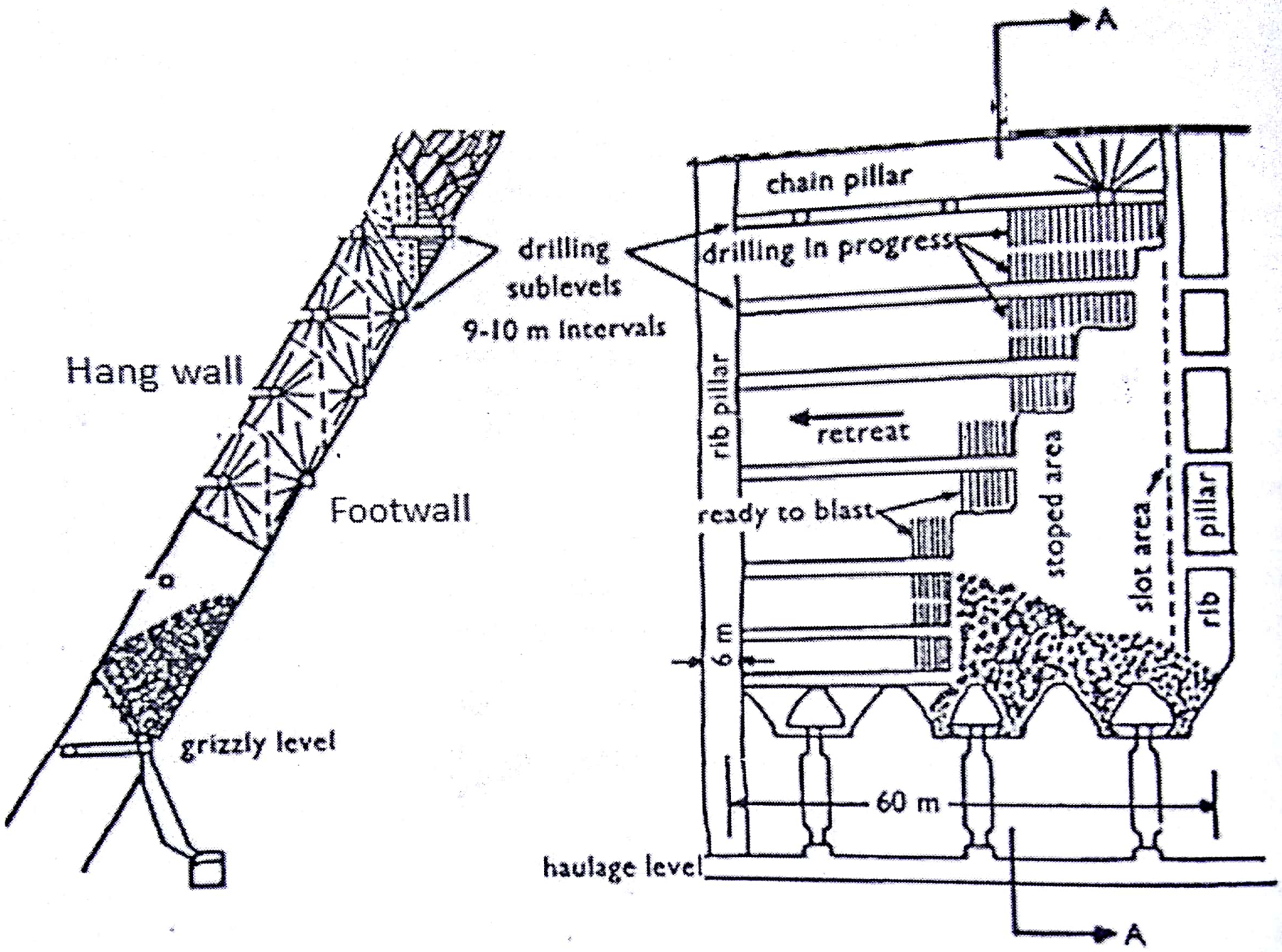

Figure Transverse and longitudinal sections of sub-level stoping method

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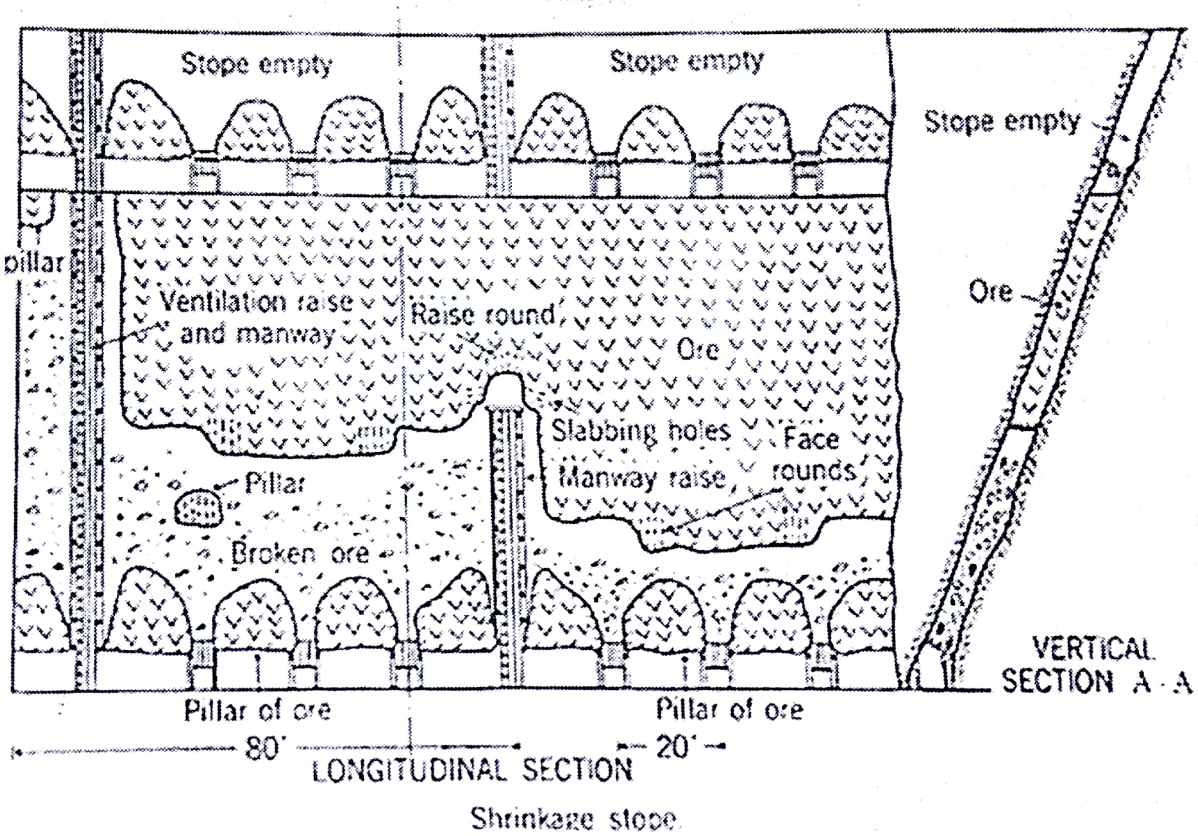

Fig. Longitudinal and cross section of shrinkage stoping

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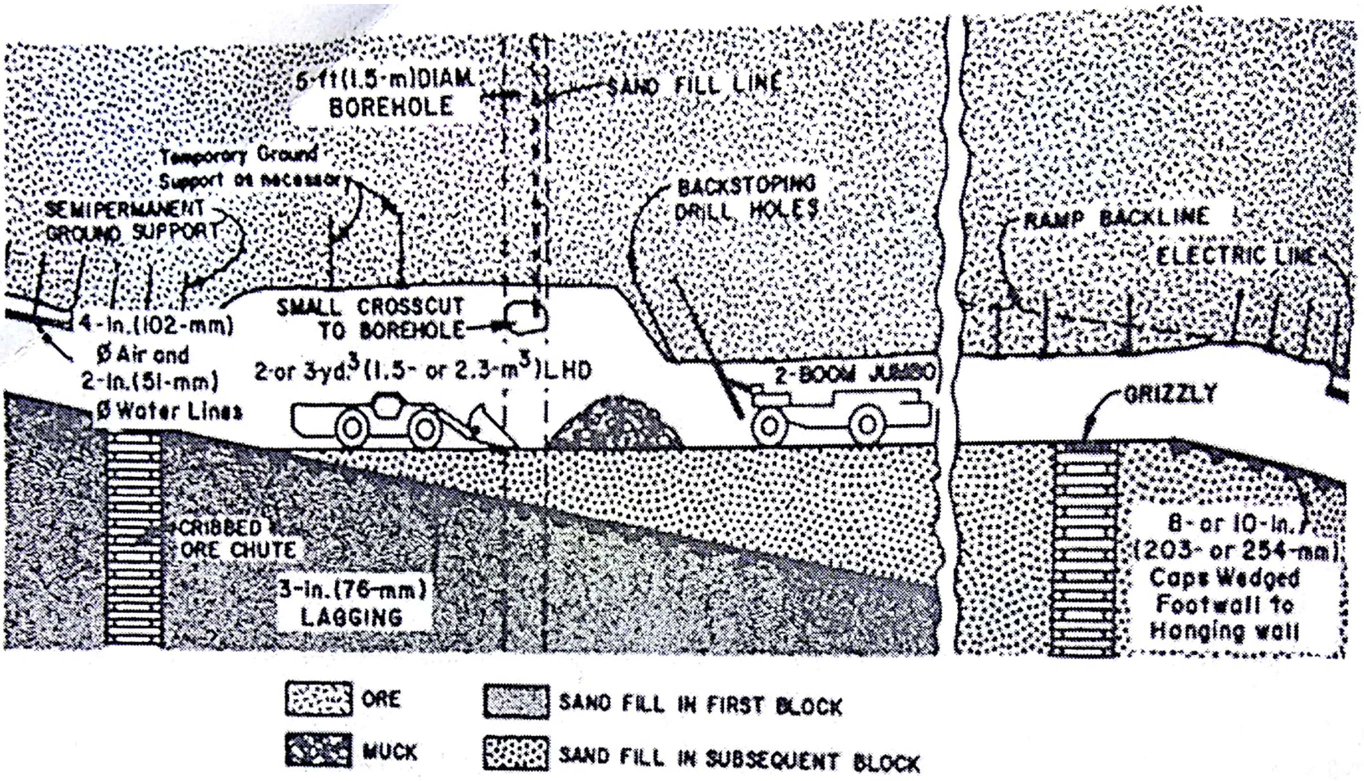

Figure Longitudinal section of a Cut-and-Fill Stope

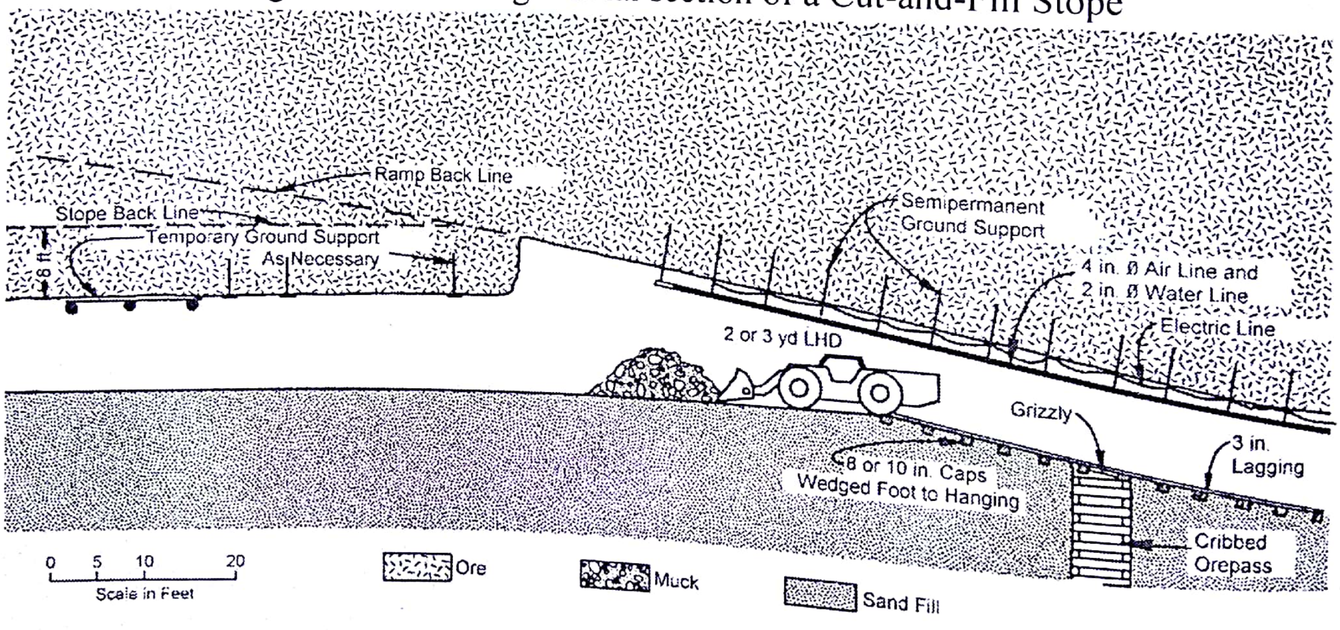

Fig Cut-and-Fill stoping operation

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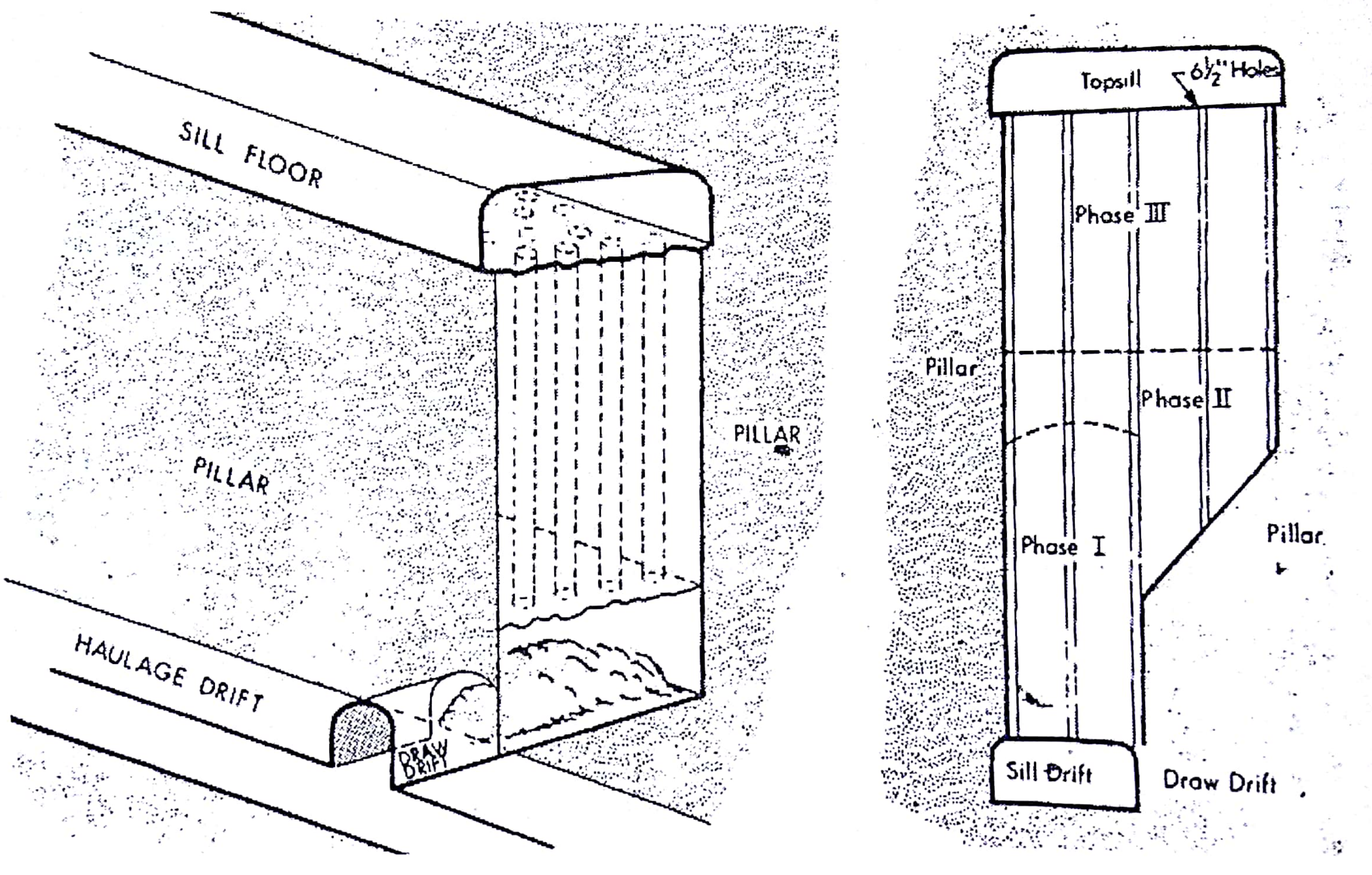

Figure Vertical Crater Retreat method

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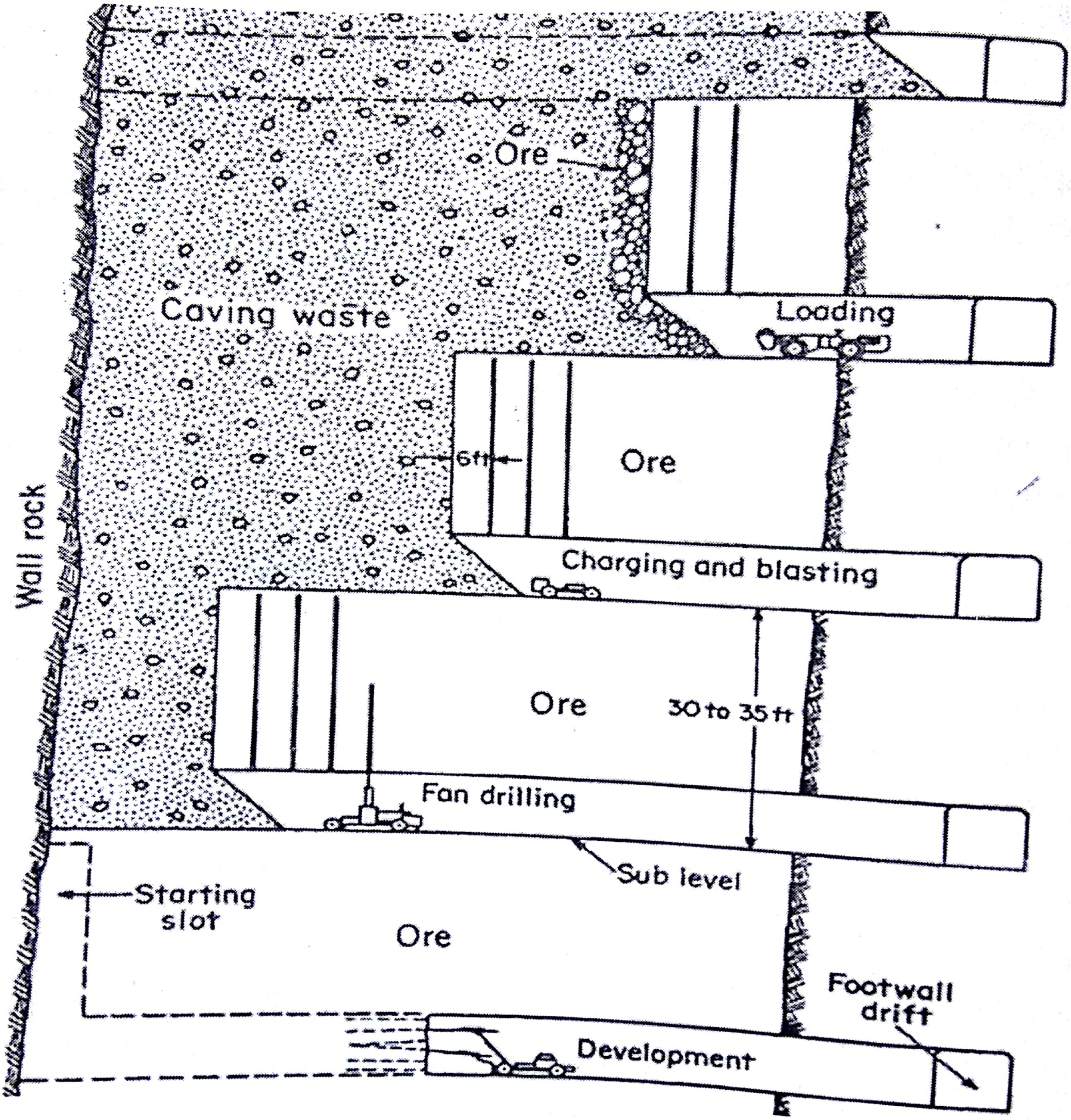

Figure **Sub-level caving details**

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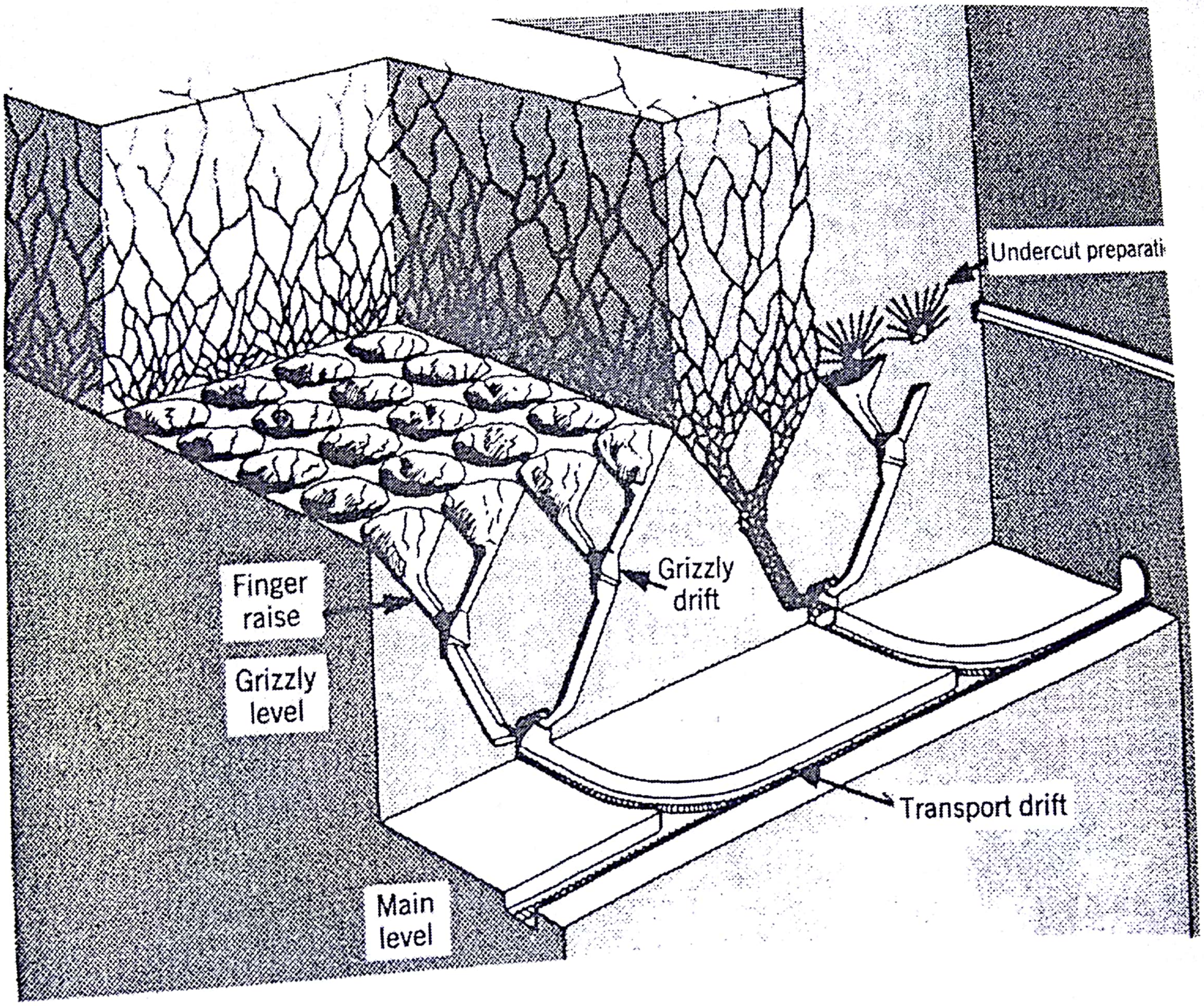

Figure Block Caving

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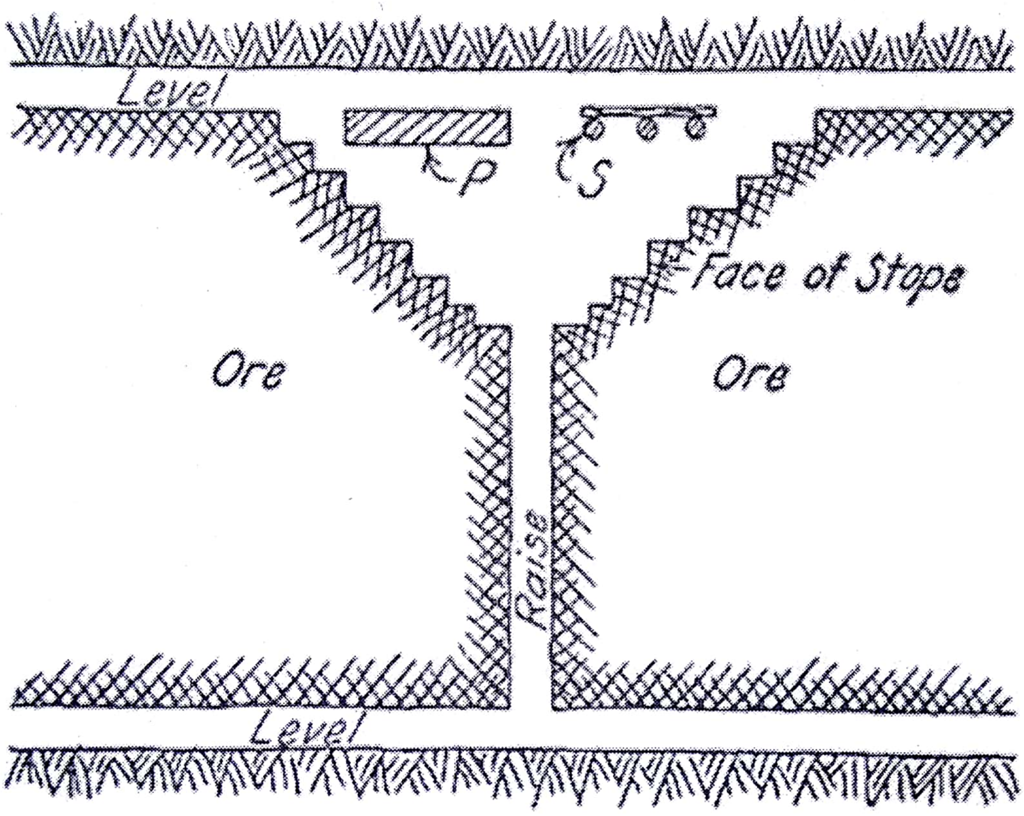

Fig Underhand stoping operation

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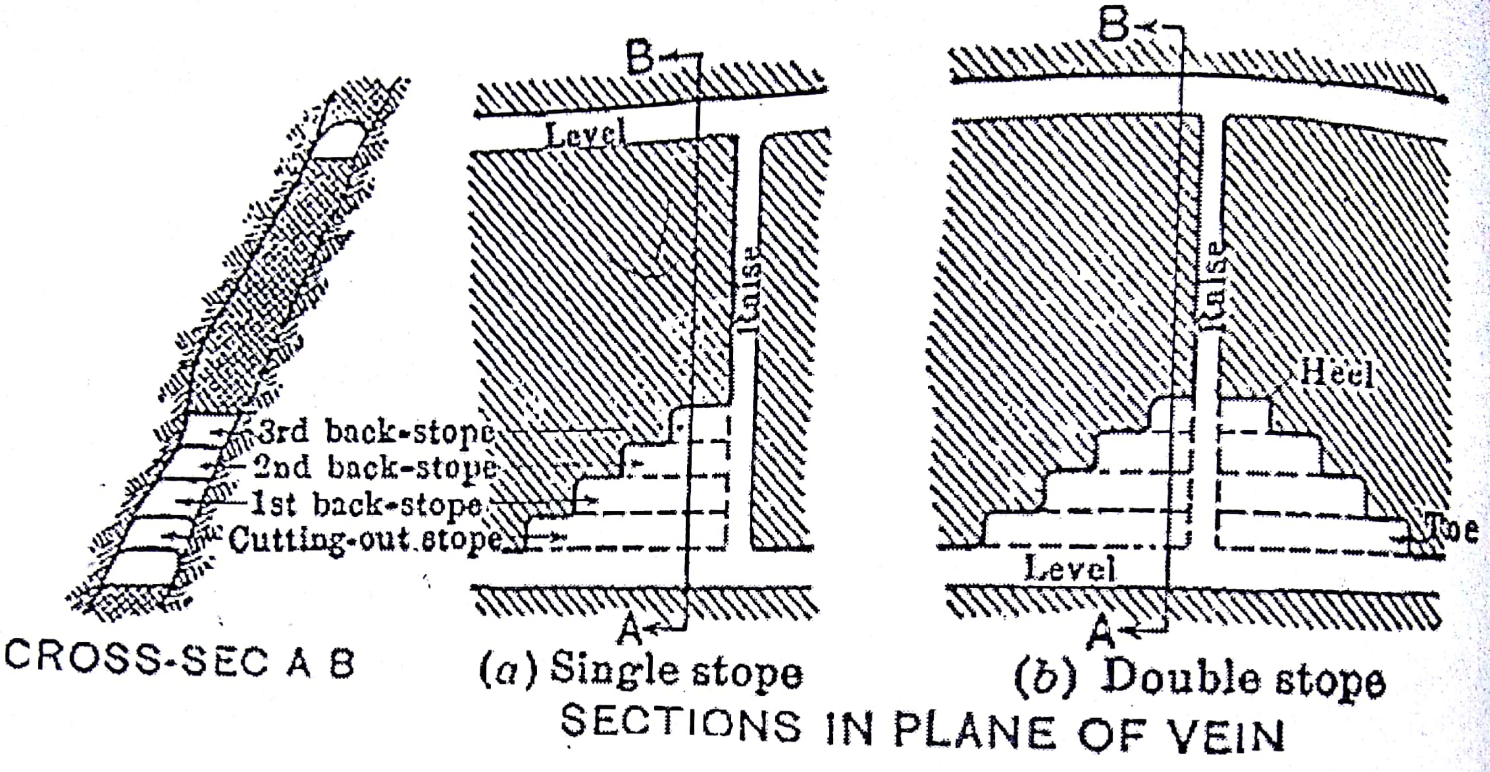

Fig. Overhand stoping operations

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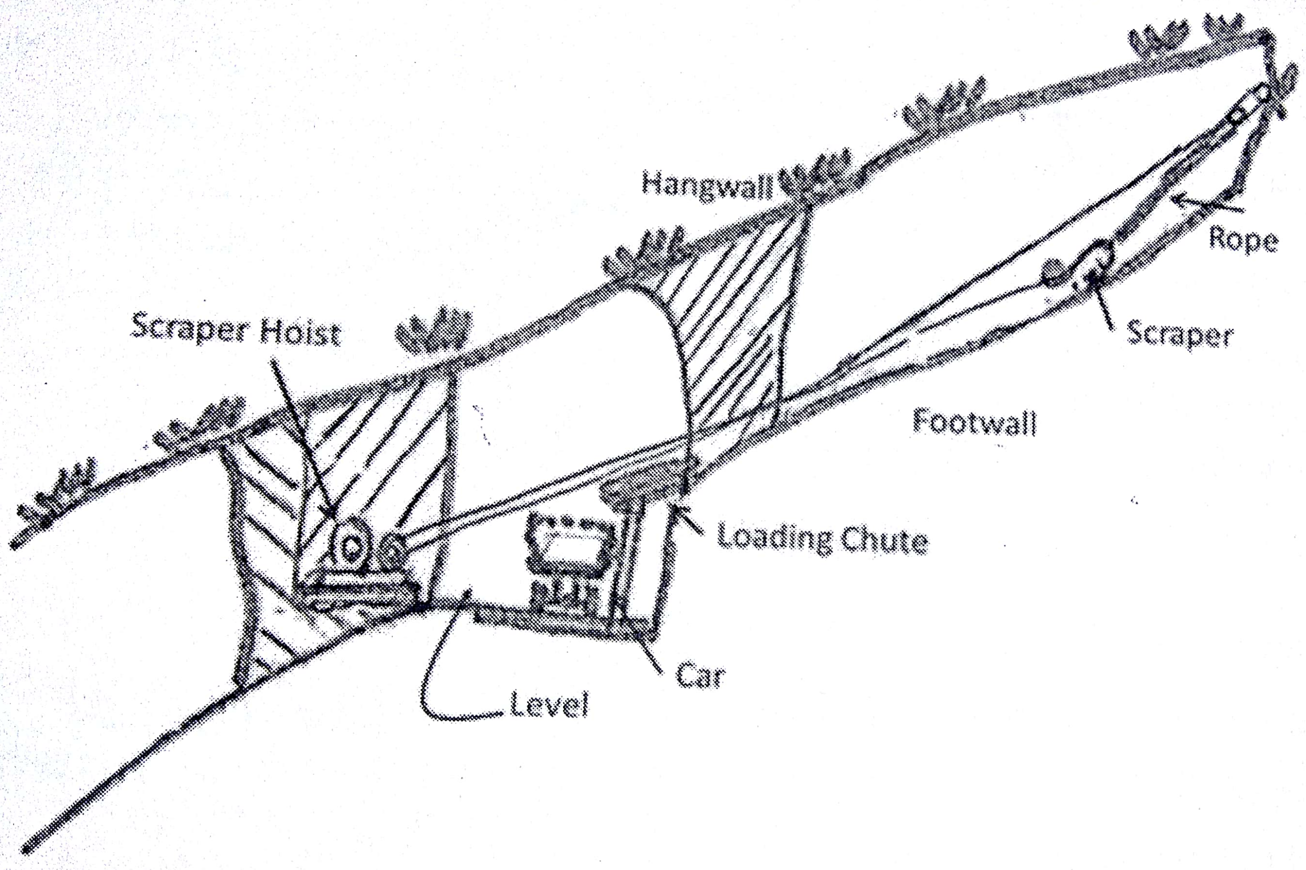

Fig. Breast stope

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